REPORT

FUNCTIONING OF THE 20 MM GUN, M2 (OLDS), NO. 30013 WITH AN INCREASE IN THE RATE OF FIRE

BY

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Abstract

The highest average rate of fire observed was 837 shots per minute. At this speed the ring spring buffer was driven solid and the M1 feed failed to maintain its winding. The forces at the trunnions were not excessive.

An average rate of approximately 750 shots per minute is the highest rate that can be expected with proper functioning of the gun and feed.

INTRODUCTION

1. The Chief of Ordnance directed in OO 492.91/4262, APG 472.5/317-790 that an investigation be made to obtain the highest possible rate of fire and still maintain proper functioning of the gun.

2. Proper functioning of the gun in this test is defined as follows:

a. there should be sufficient recoil to maintain winding of the M1 feed;

b. the velocity of the bolt should be low enough so that the back plate buffer will not be driven solid; and

c. the trunnion reactions should be reasonably low.

3. From past firings the following had been observed:

a. The gun recoil distance was decreased as the rate of fire was increased by enlarging the gas vents.

b. The maximum rate of fire for any one condition of driving spring or gas vents occurred when the impact between the bolt and the buffer came just before the gun returned into battery after recoiling.

c. When the rate of fire is increased by the shortening of the driving spring (all else remaining constant), the time ratio between the recoil and the counter-recoil of the bolt is approximately 1:2. With a sufficiently strong spring this ratio becomes approximately 1:1.

d. The time of counter recoil of the bolt is shortest with a coil spring back plate buffer plus a strong driving spring.

e. The coil spring buffer was compressed solid at approximately 675 shots per minute, while the ring spring buffer seemed not to go solid until a rate of fire above 750 shots per minute was reached.

4. From the above observations it appeared that the M1 adapter was not suitable for this test, inasmuch as certain adjustments in the recoil of the gun must be made as the rate of fire was increased. The standard front spring adapter was selected because its recoil spring produced a much faster counter-recoil and was more easily adjusted. To eliminate the high counter-recoil forces, the air piston was replaced by a ring spring counter-recoil unit.

MATERIEL AND APPARATUS

5. The following materiel and apparatus was used in this test:

a. 20 mm Gun, M2 (Olds), No. 30013; Tube No. 30021. Rounds fired previous to this test, 5307.

b. Adapter, M1. Standard front spring with air piston replaced by a ring spring counter-recoil unit.

c. Bolt, latest type extractor, solid slides and floating firing pin.

d. Buffer, combination coil and ring spring.

e. Feeds, M1; Drum.

f. Ammunition, Ball. Lot Nos. 3-50243-259 and 1-50422-7.

g. One solenoid coil plus the cathode ray oscillograph to obtain cyclic rate.

h. Piezo-electric gages and the cathode ray oscillograph to determine the forces at the trunnions.

i. A displacement-time camera to record the movements of the gun and bolt.

PROCEDURE AND RESULTS

6. Two short driving springs were selected: one with a free height of 23.7 in. (k = 7.7 lbs. per in.); and the other with a free height of 23.2 in. (k = 7.2 lbs. per in.). When the size of the vents was varied (from .068 to .080 in.) it became apparent that the stronger spring produced the better rates of fire, therefore the weaker spring was discarded. In order to maintain sufficient recoil to wind the M1 feed and to keep the impact between bolt and buffer near the end of counter-recoil, the assembled height of the recoil spring was varied (11.94 in., 11.44 in., and 11.31 in.).

The highest average rate of fire for a 7 or 10 round burst was 837 shots per minute. This was obtained with: driving spring, free height, 23.7, k = 7.7 lbs/in; gas vents, .080 in.; assembled length of the recoil spring, 11.31 in.; and the breech lock ground on the upper rear corners.

7. When the above assembly was fired with the M1 adapter replacing the coil and ring spring units, the resulting rates of fire were much lower. The drum feed with a muzzle brake was also tried.

8. The forces at the trunnions were determined. The greatest forces observed were: in the direction of recoil, 1260 lbs.; in the direction of counter-recoil, 2610 lbs.

9. The functionning characteristics of each round are given in Tables 1A and 1B. Supplementing these tables are the following charts: Figure 1, Displacement vs. time tracing of a single round taken from a ten round burst; Figure 2, the velocity of the bolt at the end of unlocking and at the beginning of buffer compression, the firing pin velocity, and the buffer compression, all as functions of the rate of fire; Figure 3, Calibration curves of the recoil spring and counter-recoil ring spring unit.

ACCURACY

10. The following accuracies apply to the reading of the records only.

a. Displacements, ± .03 inch.

b. Trunnion reactions, ± 20 lbs.

c. Cyclic rates, ± 3 shots per minute.

DISCUSSION

11. In the above test it was noted that:

a. As the rate of fire was increased through the enlarging of the gas vents, the recoil distances became shorter. This was to be expected, however, since the increase in energy expended to blow the bolt rearward with greater velocity detracted from the energy of the recoil of the gun.

b. At a rate of fire of about 800 shots per minute, the ring spring buffer was driven solid.

c. Also at the rate of fire of 800 shots per minute, the movement of the gun was too fast to allow the feed to function properly. Consequently, even though some of the recoils were sufficiently long, the feed lost winding on every round.

d. No malfunctions of any nature were observed, except the non-winding of the feed at the rate of fire mentioned.

12. Although comparatively few rounds were fired, there are indications that much higher rates of fire could be obtained, depending, however, upon some rather drastic changes in the gun. The most important changes are:

a. A readjustment of the M1 adapter for shorter recoil distances.

b. A redesign of the back plate buffer.

c. The use of the drum feed or the design of a new feed (preferably a built-in feed divorced from the recoil of the gun) which will function much more quickly on shorter recoil distances.

13. The readjustment of the adapter will be simple in that the initial compression of the coil spring should be increased to approximately 580 lbs. (The rate of the standard coil spring is almost the same as that of the coil spring in the M1 adapter.)

14. The back plate buffer can be redesigned to inclose a much heavier coil spring. (A sketch of a proposed change is included herewith.) Based on a rate of 1000 shots per minute, the buffer spring should have: initial compression, 700 lbs.; and k, 2200 lbs. per inch. With these characteristics the back plate will be able to absorb the energy of the bolt when it hits the buffer at approximately 40 ft. per second.

15. Due to the construction of the gun there are three sources of energy which may be tapped to operate a mechanical feed. These are: (1) the recoil of the entire gun, (2) the gas piston, and (3) the bolt. The M1 feed, wound by the recoil of the gun, is fairly satisfactory at rates of fire up to 750 shots per minute, but does not function at speeds above 800 shots per minute. Winding of the M1 feed has been accomplished through the action of the gas piston rod, but the rate of fire was relatively low even though the gas vents were considerably enlarged. At high speed, therefore, either the drum feed must be used or a feed constructed that is not altogether dependent on the recoil. The power for such a feed may be obtained either from the bolt or from a combination of the recoil and gas cylinder piston rod. From automatic guns already in use it appears that power from the bolt could be used more simply and efficiently; yet it is doubtful if a rate of fire equal to that of a drum feed could be obtained.

16. Rates of fire above those observed in this test may also be obtained by:

a. Cutting down the time in which the bolt is locked.

b. Increasing the forward velocity (firing pin velocity) of the slides.

c. Increasing the rearward velocity of the bolt.

d. Increasing the forward velocity of the bolt.

17. In order to decrease the time that the bolt remains in the locked position, it is possible to increase the diameter of the gas vents, to move the gas port rearward so that unlocking occurs sooner or to combine both of these methods.

18. If the forward velocity (firing pin velocity) of the slides is increased, the firing of the primer can be accomplished more quickly, thereby reducing the time per cycle by 2 or 3 milli-seconds. Increasing the firing pin velocity is effected by grinding the upper and lower rear edges of the breech lock and the lower rear edges of each slide so as to lessen considerably the impact between breech lock and slides when locking occurs. Firing pin velocities approaching the terminal velocity of the bolt may be obtained in this manner.

19. The rearward velocity of the bolt is a function of the blowback pressure at unlocking and the velocity with which the gas cylinder rod moves during the last quarter inch of its travel. Increasing this rearward velocity can be brought about either by enlarging the gas vents or by moving the gas port rearward.

20. The forward velocity of the bolt may be increased by:

a. A coil spring in the buffer (with low hysteresis) so that the velocity of the bolt when it leaves the buffer is equivalent to the velocity upon impact.

b. A proper selection of the driving spring.

CONCLUSION

21. The following conclusions are drawn:

a. The gun as is, when equipped with a ring spring buffer and properly selected gas vent, driving spring and recoil spring, can be made to fire 750 shots per minute without undue hardship on the mechanism.

b. There is sufficient evidence from the firings to show that the rate of fire may be increased to approximately 1000 shots per minute by:

1) Proper adjustment of the recoil and driving springs and gas vents.
2) Using the drum feed or constructing a feed which will operate much faster and on less recoil than the M1 feed.
3) Designing a back plate buffer capable of absorbing at least 1400 in.-lbs. of energy before going solid.

c. Excessive crush of the forward end of the case and gouging of the rim may occur at this speed, but this was not indicated in the firings.

22. The functioning of the gun as given in this report is in relation to a very rigid mount. Where the degree of flexibility is different, a difference in the functioning will probably be noted.

Richard F. Cronin

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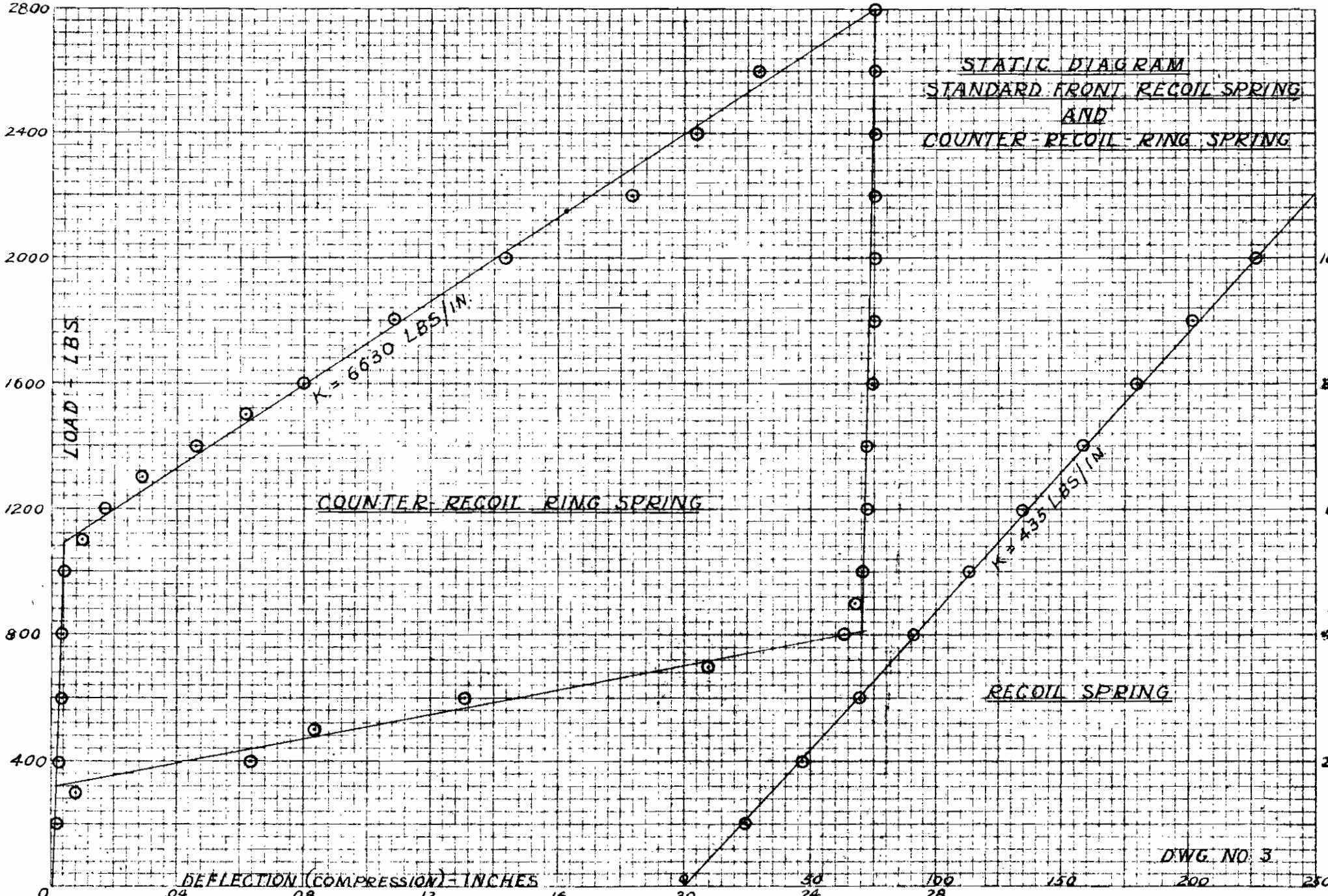
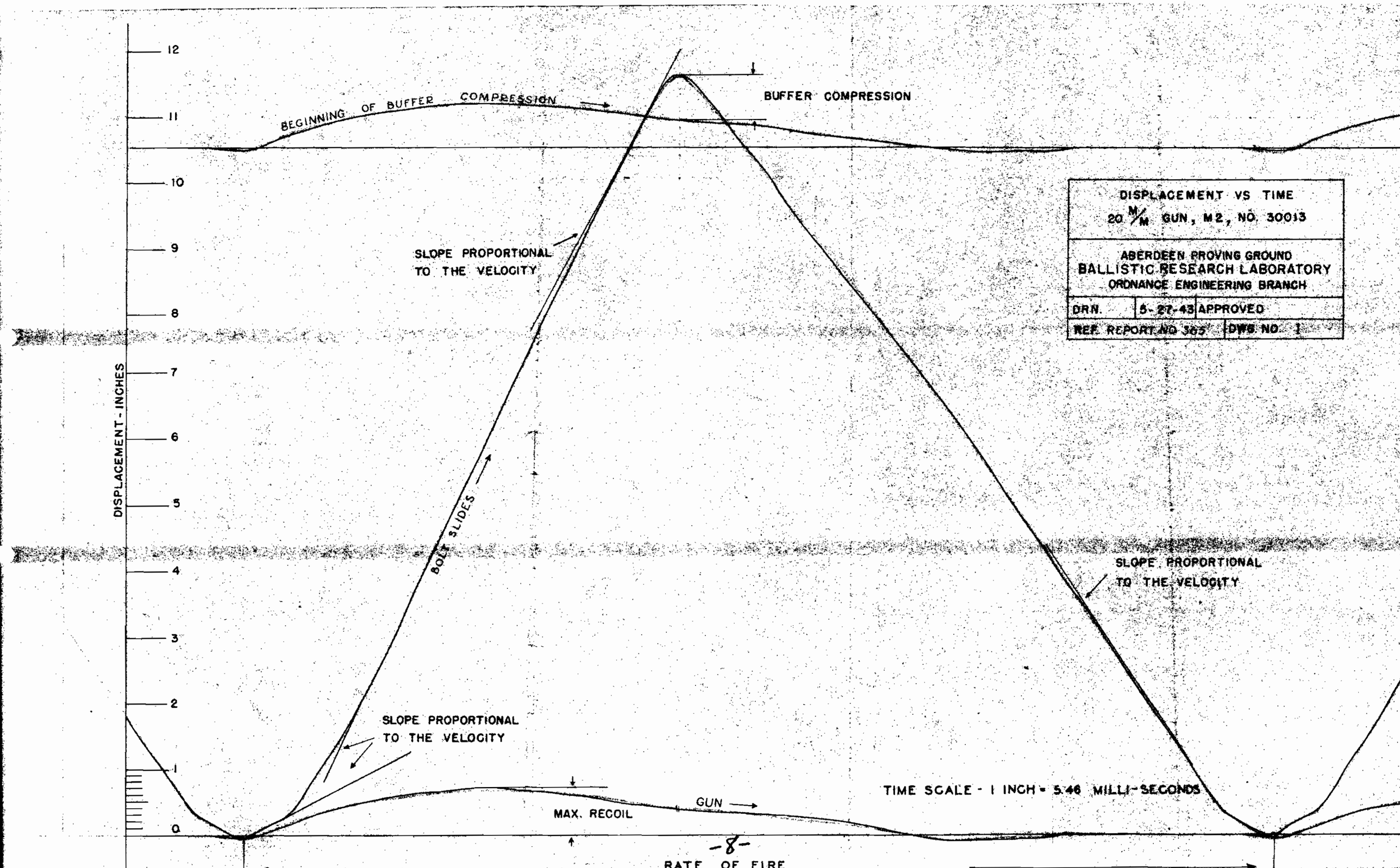

STATIC DIAGRAM
STANDARD FRONT RECOIL SPRING
AND
COUNTER-RECOIL-RING SPRING
COUNTER RECOIL RING SPRING
K = 6630 LBS/IN.
K = 435 LBS/IN.
RECOIL SPRING
LOAD - LBS.
DEFLECTION (COMPRESSION) - INCHES
2800
2400
2000
1600
1200
800
400
0
.04
.08
.12
.16
.20
.24
.28
50
100
150
200
250
1000
800
600
400
200
DWG. NO. 3



DISPLACEMENT VS TIME
20 M/M GUN, M2, NO. 30013

ABERDEEN PROVING GROUND
BALLISTIC RESEARCH LABORATORY
ORDNANCE ENGINEERING BRANCH

DRN.	5-27-43	APPROVED
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HIGH SPEED FUNCTIONING
20 MM GUN MZ NO 30013

ABERDEEN PROVING GROUND
BALLISTIC RESEARCH LABORATORY
ORDNANCE ENGINEERING BRANCH

DRN | 3-28-45 | APPROVED
REF REPORT NO 365 | DWG NO 2

BREECH BLOCK LOCK GROUND AT THIS POINT

MAX BUFFER COMPRESSION - IN.

MAX RECOIL DIST - IN.

FIRING PIN VELOCITY AT BEGINNING OF BUFFER COMPRESSION - F/S

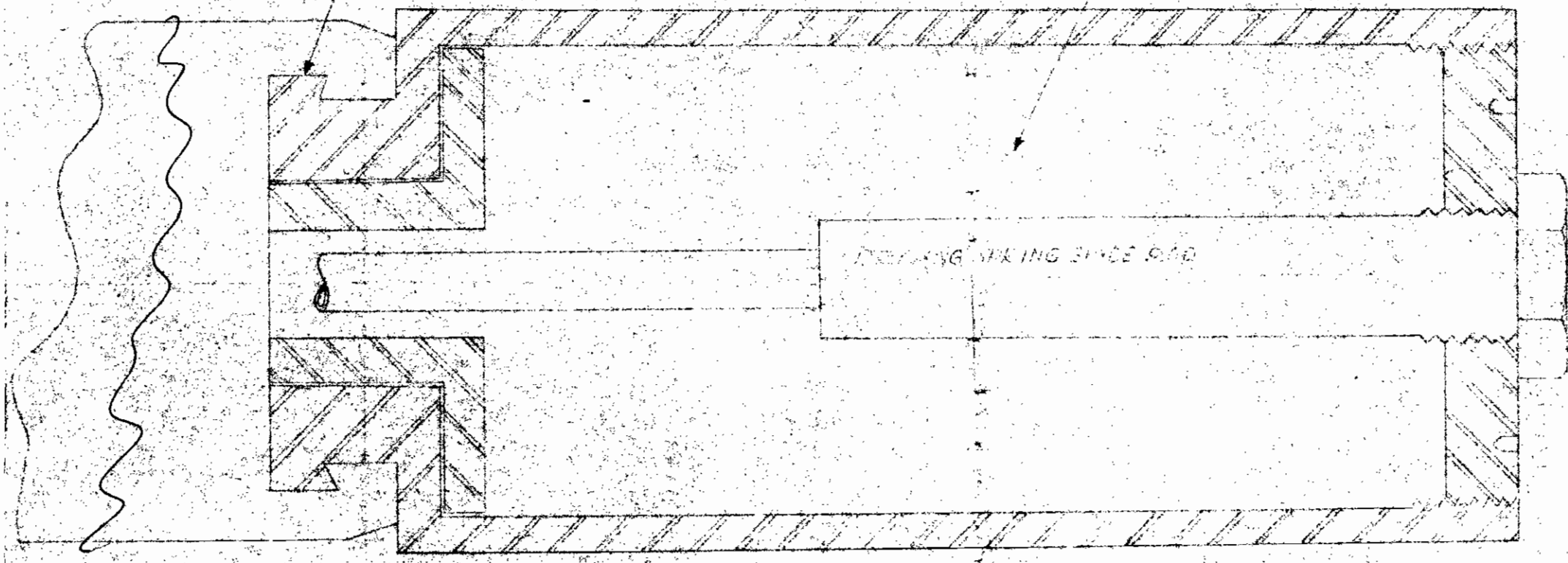
VELOCITY OF BOLT AT UNLOCKING - F/S

RATE OF FIRE - SHOTS/MIN.

-9-

BUFFER MAY BE HELD IN POSITION BY LATCHES, ONE ON EACH SIDE OF RECEIVER

COIL SPRING, K = 2 200 lbs/in
INITIAL COMPRESSION, 500 lbs.
DIMENSIONS OF BUFFER ARE TO BE CHANGED TO SUIT TYPE OF SPRING USED.



PROPOSED BACK PLATE BUFFER
FOR HIGH SPEED 20 M/M GUN

ABERDEEN PROVING GROUND
BALLISTIC RESEARCH LABORATORY
ORDNANCE ENGINEERING BRANCH

DRN. MCS	6-4-47	APPR.	SCALE 1
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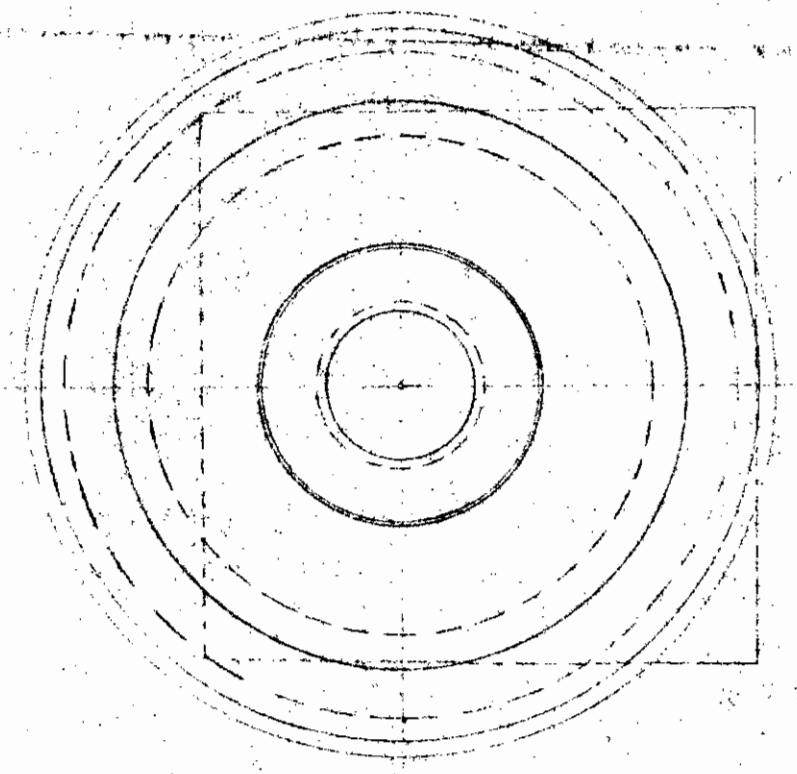

TABLE I

Results of Increasing the Rate of Fire
20 m/m Gun, M2 (Olds), No. 30013, Tube No. 30021; Feed, M1 (C.F.S.)
Buffer, Combination Ring and Coil Spring

Gun Rd. No.	Amm. Lot No.	Max. Recoil	Max. Buffer Comp.	Velocity of Bolt at unlocking	Velocity of Bolt at beginning of buffer	Firing Pin Velocity	Position of Slides Relative to the Bolt at beginning of unlocking	Rate of Fire Per Round	Rate of Fire Average
		in.	in.	f/s	f/s	f/s	in.	s/m	
Standard Front Recoil Spring and Edgewater Ring Spring Counter-recoil unit. Gas Vents, .068 in; Driving Spring, Free ht. = 23.7 in.; k = 7.7 lbs/in. Recoil Spr. Ass. Ht., 11.31 in.									
5310	Ball	.75	.43	26.4	15.5	9.8	.12	652	
5311	3-50243-	.71	.47	26.9	—	12.0	.15	668	
5312	259	.69	.42	27.9	--	12.5	.11	660	
5313		.79	.43	28.1	15.3	12.0	.13	653	
5314		.81	.44	27.9	17.0	11.9	.10	678	667
5315		.83	.43	28.3	16.7	11.5	.09	663	
5316		.86	.41	28.3	14.2	9.5	.14	660	
5317		.83	—	26.2	--	11.9	.10	686	
5318		.84	.42	27.6	--	11.9	.09	687	
5319		--	—	28.9	17.6	13.0	.09	—	
Gas Vents, .075 in. Driving Spring, Free Ht. = 23.7 in.; k = 7.7 lbs/in.									
5320	"	.85	.55	31.8	—	9.5	.20	728	
5321		.72	.55	29.2	—	10.7	.11	723	
5322		.74	.54	30.5	—	12.6	.09	717	
5323		.76	.54	29.9	—	9.7	.15	721	
5324		.77	—	30.0	—	12.5	.11	712	
5325		.85	—	28.6	—	10.7	.13	694	709
5326		.85	—	29.1	--	12.2	.09	698	
5327		.81	.52	29.9	—	10.9	.09	692	
5328		.85	—	29.1	—	11.5	.15	701	
5329		.84	--	30.2	—	12.3	.09	707	
5330		--	—	31.7	--	11.7	—	—	

12

TABLE I

Results of Increasing the Rate of Fire
20 m/m Gun, M2 (olds), No. 30013, Tube No. 30021; Feed, M1 (C.F.S.)
Buffer, Combination Ring and Coil Spring

Gun Rd. No.	Amm. Lot No.	Max. Recoil	Max. Buffer Comp.	Velocity of Bolt at unlocking	Velocity of Bolt at beginning of buffer	Firing Pin Velocity	Position of Slides Relative to the Bolt at beginning of unlocking	Rate of Fire Per Round	Rate of Fire Average
		in.	in.	f/s	f/s	f/s	in.	s/m	
Gas Vents, .075 in., Driving Spring, Free Ht., = 23.2 in., k = 7.2 lbs/in.									
5331	Ball	.69	.52	—	26.4	9.0	.14	770	
5332	3-50243-	.69	.54	—	—	12.6	.08	743	
5333	259	.69	.53	—	—	12.6	.11	750	
5334		.71	.52	—	25.9	11.4	.08	752	
5335		.77	—	—	—	10.2	.11	733	743
5336		.72	—	—	—	11.0	.11	735	
5337		.75	.43	—	22.6	12.6	.12	720	
5338		.76	—	—	—	9.9	.08	746	
5339		.80	—	—	—	10.1	.10	740	
5340		—	—	—	—	10.1	.11	—	
5341	"	.80	.45	29.3	22.8	8.7	.17	722	
5342		.72	.45	30.2	23.0	10.4	.09	737	
5343		.77	.47	30.2	—	10.5	.13	716	
5344		.76	.44	31.5	—	10.4	.09	737	
5345		.76	—	29.5	—	10.6	.13	765	727
5346		.79	.45	29.1	—	10.2	.13	712	
5347		.80	.42	30.2	—	9.9	.14	714	
5348		.82	.46	31.3	—	10.6	.09	727	
5349		.83	.40	29.1	—	9.9	.12	716	
5350		—	—	29.3	—	9.4	.13	—	

TABLE I

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Buffer, Combination Ring and Coil Spring

Gun Rd. No.	Amm Lot No.	Max. Recoil	Max. Buffer Comp.	Velocity of Bolt at unlocking	Velocity of Bolt at beginning of buffer	Firing Pin Velocity	Position of Slides Relative to the Bolt at beginning of unlocking	Rate of Fire Per Round	Rate of Fire Average
		in.	in.	f/s	f/s	f/s	in.	s/m	
Vents, .075 in., Driving Spring, Free Ht. = 23.7, k = 7.7 lbs/in.									
5351		.72	--	30.8	—	8.9	.14	747	
5352		.67	—	30.4	--	13.0	.08	716	
5353		.70	--	31.0	—	10.6	.09	722	
5354		.78	--	31.7	—	9.5	.11	715	
5355		.79	—	32.5	—	12.1	.11	748	725
5356		.74	—	31.0	—	10.3	.10	721	
5357		.57	--	32.2	—	10.6	.09	715	
5358		.78	—	32.5	--	10.8	.11	717	
5359		.76	—	32.8	--	9.8	.11	~~737~~	
5360		—	—	31.7	--	12.8	.12	---	
Gas Vents, .075 in.; Driving Spring, Free Ht. = 23.7, k = 7.7 lbs/in.; Ground Breech Lock									
5361		.82	.51	30.7	23.2	9.5	.12	773	
5362		.63		32.0		13.5	.09	755	
5363		.63		33.0		12.1	.14	766	
5364		.65		32.0		12.9	.12	735	746
5365		.70		29.3		13.9	.09	722	
5366		.76		34.4		11.1	.10	747	
5367		.75		31.7		13.4	.08	739	
5368		.79		32.0		13.7	.09	717	
5369		.74		31.7		12.3	.09	764	
5370		—		33.3		13.4	.09	---	

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Buffer, Combination Ring and Coil Spring

Gun Rd. No.	Amm. Lot No.	Max. Recoil	Max. Buffer Comp.	Velocity of Bolt at unlocking	Velocity of Bolt at beginning of buffer	Firing Pin Velocity	Position of Slides Relative to the Bolt at beginning of unlocking	Rate of Fire Per Round	Rate of Fire Average
		in.	in.	f/s	f/s	f/s	in.	s/m	
5371		.71	.59	33.0	26.8	9.7	.21	800	
5372		.56	.53	31.9	—	15.4	.10	789	
5373		.60		31.0	—	12.9	.08	615	
5374		.67		33.6	—	11.9	.08	816	
5375		.81		33.0	—	14.8	.11	745	747
5376		.75		32.2	—	11.0	.11	740	
5377		.73		31.6	—	10.6	.08	742	
5378		.79	.49	31.6	—	11.7	.10	737	
5379		.78		31.9	—	11.4	.14	741	
5380		—		31.6	—	12.8	.08	—	
5381		.78	—	32.2	—	9.5	.13	747	
5382		.65	—	32.7	—	11.5	.12	778	
5383		.66	—	32.7	—	11.4	.10	675	
5384		.68	—	31.6	—	13.1	.10	743	
5385		.75	—	32.2	—	10.9	.10	754	744
5386		.66	—	33.2	—	15.7	.14	786	
5387		.78	—	31.6	—	16.0	.07	735	
5388		.73	—	34.4	—	13.1	.07	766	
5389		.85	—	29.4	—	13.2	.14	714	
5390		—	—	33.0	—	12.7	.11	—	

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Buffer, Combination Ring and Coil Spring

Gun Rd. No.	Amm. Lot No.	Max. Recoil	Max. Buffer Comp.	Velocity of Bolt at unlocking	Velocity of Bolt at beginning of buffer	Firing Pin Velocity	Position of Slides Relative to the Bolt at beginning of unlocking	Rate of Fire Per Round	Rate of Fire Average
		in.	in.	f/s	f/s	f/s	in.	s/m	
				Assembled Ht. of Recoil Spring 11.94 in. Vents, .080 in.					
5391		.87	—	32.1	--	9.8	.16	734	
5392		.98	—	33.6	--	12.4	.11	715	
5393		.97	—	32.2	—	11.9	.08	735	
5394		.98	—	33.0	—	13.1	.08	733	
5395		.87	—	33.2	--	13.3	.07	733	729
5396		.86	—	33.0	--	13.0	.11	728	
5397		.86	—	34.4	—	12.3	.11	707	
5398		.86	—	31.0	—	12.0	.07	722	
5399		.87	—	33.0	--	12.8	.12	754	
5400		—	--	33.0	—	12.9	.08	---	
				Assembled Ht. of Recoil Spring 11.31 in. Vents, .080 in.					
5401		.59	—	34.0	--	9.7	.14	830	
5402		.45	—	37.3	—	14.3	.08	812	
5403		.51	—	35.1	—	11.3	.11	789	
5404		.56	—	34.7	—	12.4	.11	807	
5405		.62	—	33.0	—	13.6	.11	780	
5406		.63	—	33.6	—	12.8	.11	789	801
5407		.65	—	36.6	—	13.3	.07	795	
5408		--	--	35.8	—	13.3	.06	794	
5409		—	—	39.0	--	14.5	.04	---	

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Gun Rd. No.	Amm. Lot No.	Max. Recoil	Max. Buffer Comp.	Velocity of Bolt at unlocking	Velocity of Bolt at beginning of buffer	Firing Pin Velocity	Position of Slides Relative to the Bolt at beginning of unlocking	Rate of Fire Per Round	Rate of Fire Average
		in.	in.	f/s	f/s	f/s	in.	s/m	
				Recoil Spring Assembled Ht. = 11.31 in.; Vents, .030					
5410		.59	.59	33.2	27.8	9.3	.20	845	
5411		.48	.54	33.4	27.8	15.9	.06	805	
5412		.57	.63	33.2	27.4	15.4	.08	811	
5413		.53	.61	35.2	29.4	13.8	.16	806	
5414		.55	.61	34.8	28.2	15.4	.08	823	810
5415		.58	.60	34.6	26.7	12.6	.07	803	
5416		lost	lost	35.0	33.9	13.4	lost	800	
5417		—	—	34.6	—	14.9	—	785	
5418		—	—	—	—	14.4	—	lost	
5419		—	—	34.9	31.9	—	—	—	
				Vents, .080 in.; Muzzle brake and drum feed					
5420		.47	.61	36.7	29.7	9.5	.22	848	
5421		.39	—	36.4	29.7	14.6	.06	775	
5422		.41	.52	36.2	26.4	11.9	.12	775	
5423		—	—	36.2	30.0	15.2	.07	784	
5424		—	—	35.8	26.4	15.0	.06	774	788
5425		.45	.54	34.7	25.5	13.0	.13	769	
5426		—	—	37.5	29.0	15.0	—	774	
5427		—	.56	37.9	27.3	12.0	—	794	
5428		—	.57	36.2	34.8	15.0	—	798	
5429		—	—	34.7	30.0	14.1	—	—	

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TABLE I

Results of Increasing the Rate of Fire
20 m/m Gun, M2 (Olds), No. 30013, Tube No. 20031; Feed, M1 (C.F.S.)
Buffer, Combination Ring and Coil Spring

Gun Rd. No.	Amm. Lot No.	Max. Recoil	Max. Buffer Comp.	Velocity of Bolt at unlocking	Velocity of Bolt at beginning of buffer	Firing Pin Velocity	Position of Slides Relative to the Bolt at beginning of unlocking	Rate of Fire Per Round	Rate of Fire Average
		in.	in.	f/s	f/s	f/s	in.	s/m	
Vents, .070 in.; Recoil Spring Assembled Ht., 11.31 in.; M1 Feed									
5430		.66	.46	34.4	15.8	9.5	.13	667	
5431		.66	.29	29.8	23.6	14.5	.10	754	
5432		—	.51	29.2	22.9	13.6	.07	738	
5433		.65	.56	32.3	23.6	13.4	.11	765	
5434		.63	.50	32.3	25.9	14.6	.08	776	751
5435		.74	.51	28.6	22.6	—	.08	727	
5436		.88	.54	27.0	25.6	12.9	.08	742	
5437		.81	.50	25.5	21.0	11.8	.23	794	
5438		.69	.66	31.6	25.8	10.6	.17	792	
5439		—	.52	31.9	26.0	10.8	.10	—	
Vents, .070 in. Recoil spring assembled Ht. 11.44 in.									
5440		.64	.53	29.5	22.0	8.6	.13	737	
5441		.65	.54	27.3	23.6	15.2	.08	751	
5442		.72	.51	29.9	23.6	13.0	.11	721	
5443		.72	.48	30.4	22.4	12.1	.19	710	
5444		.78	--	28.4	22.8	12.1	.13	707	732
5445		.74	.60	33.2	25.9	10.6	.13	739	
5446		.75	.54	33.2	25.6	14.5	.17	748	
5447		.83	—	32.0	26.4	—	--	736	
5448		.84	.55	33.2	26.4	—	--	739	
5449		—	—	33.9	26.4	12.4	.12	---	

TABIE I

Results of Increasing the Rate of Fire
20 m/m Gun, M2 (Olds), No. 30013, Tube No. 30021; Feed, M1 (C.F.S.)
Buffer, Combination Ring and Coil Spring

Gun Rd. No.	Amm. Lot No.	Max. Recoil	Max. Buffer Comp.	Velocity of Bolt at unlocking	Velocity of Bolt at beginning of buffer	Firing Pin Velocity	Position of Slides Relative to the Bolt at beginning of unlocking	Rate of Fire Per Round	Rate of Fire Average
		in.	in.	f/s	f/s	f/s	in.	s/m	
Adapter, M1; Vents, .070 in., Driving Spring, Free Ht. 23.7 in., k = 7.7 lbs/in.									
5450		.85	—	33.2	—	9.9	.20	722	
5451		.98	—	34.3	—	13.3	.22	738	
5452		1.02	—	33.8	—	15.8	.07	714	
5453		1.04	—	34.0	—	13.7	.14	720	719
5454		1.06	—	34.3	—	13.3	.10	707	
5455		1.04	—	34.1	—	14.5	.11	713	
5456		1.08	—	32.0	—	12.6	.13	702	
5457		1.07	—	33.5	—	10.6	.14	726	
5458		1.07	—	33.2	—	12.8	.13	728	
5459		—	—	32.7	—	18.8	.10	—	

TABLE II

Trunnion Reaction Maxima
20 m/m Gun, M2 (olds), No. 30013, Tube 30021
Adapter, Standard Front Recoil Spring and Ring Spring Counter-recoil Unit
Feed, Ml. Temperature 78°F (Approx.)

Gun Rd. No.	Recoil Force lbs.	Ctr.-Rec. force lbs.	Max. Recoil dist. in.	Max. Buffer Comp. in.	Rate of fire shots/m	Aver.	Vel. of bolt at beginning of buffer f/s
Recoil Spring Assembled Ht., 11.31 in.; Vents, .080 in.; Driving Spring, Free Ht., 23.7 in., k = 7.7 lbs/in.							
5463	1150	2610	.67	.59	843		30.9
5464	1250	2210	.63	.61	848		30.3
5465	1240	1990	.64	.61	827		29.8
5466	1160	1570	.55	.52	844	830	30.9
5467	1300	1770	.59	.56	812		29.8
5468	1150	2100	.61	.60	808		29.8
5469	1190	2240	.67	--	--		--
5470	1170	2010	.69	.61	839		30.3
5471	1280	1550	.52	.61	871		29.2
5472	1170	2430	.53	.61	823	837	28.6
5473	1260	1200	.57	.62	820		29.8
5474	1200	1450	.56	.61	834		32.2
5475	1120	1850	.61	.63	---		31.0